



## NASA SBIR 2022 Phase I Solicitation

### S13.05 In Situ Instruments/Technologies for Lunar and Planetary Science

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, MSFC

#### Scope Title:

In- Situ Instruments/ Technologies for Planetary Science

#### Scope Description:

This subtopic solicits development of advanced instrument technologies and components suitable for deployment on in situ planetary and lunar missions. These technologies must be capable of withstanding operation in space and planetary environments, including the expected pressures, radiation levels, launch and impact stresses, and range of survival and operational temperatures. Technologies that reduce mass, power, volume, and data rates for instruments and instrument components without loss of scientific capability are of particular importance; for both conventional missions as well as for small-satellite missions. In addition, technologies that can increase instrument resolution and sensitivity or achieve new and innovative scientific measurements are solicited. For examples of NASA science missions, see <https://science.nasa.gov/missions-page>. For details of the specific requirements see the National Research Council report "Vision and Voyages for Planetary Science in the Decade 2013-2022" (<http://solarsystem.nasa.gov/2013decadal/>, hereafter referred to as the Planetary Decadal Survey). Of particular interest are technologies to support future missions under the New Frontiers and Discovery programs.

Specifically, this subtopic solicits instrument development that provides significant advances in the following areas, broken out by planetary body:

- Mars:
  - Subsystems relevant to current in situ instrument needs (e.g., lasers and other light sources from UV to microwave, x-ray and ion sources, detectors, mixers, mass analyzers, and front-end ion/neutrals separation/transport technologies, etc.) or electronics technologies (e.g., field-programmable gate array (FPGA) and application-specific integrated circuit (ASIC) implementations, advanced array readouts, miniature high-voltage power supplies).
  - Technologies that support high precision in situ measurements of the elemental, mineralogical, and organic composition of planetary materials.
  - Conceptually simple, low-risk technologies for in situ sample extraction and/or manipulation including fluid and gas storage, pumping, and chemical labeling to support analytical instrumentation.
  - Seismometers, mass analyzers, technologies for heat flow probes, and atmospheric trace gas detectors. Improved robustness and g-force survivability for instrument components, especially for

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- geophysical network sensors, seismometers, and advanced detectors (intensified charge-coupled devices (iCCDs), photomultiplier tube (PMT) arrays, etc.).
  - Instruments geared towards rock/sample interrogation prior to sample return. Sensors to measure dimensions of laser ablation pits in natural rock samples with unprepared rough surfaces to support geochronology measurements on rock samples collected by a rover (spatial and depth resolution of 10 Åµm or better from a working distance of tens of centimeters desired to characterize ~1-mm-deep by ~0.5-mm-wide pits).
  - Technologies, concepts, or components related to active source imaging systems (e.g., light detection and ranging; lidar) for accurate and precise mobile 3D terrain mapping and navigation, with additional sensor capabilities such as velocimetry.
  - Venus:
    - Sensors, mechanisms, and environmental chamber technologies for operation in Venus's high-temperature, high-pressure environment with its unique atmospheric composition.
    - Approaches that can enable precision measurements of surface mineralogy and elemental composition and precision measurements of trace species, noble gases, and isotopes in the atmosphere.
  - Small bodies:
    - Technologies that can enable sampling from asteroids, and from within comet nuclei to provide improved *in situ* analysis of comets.
    - Imagers and spectrometers that provide high performance in low-light environments.
    - Dust environment measurements and particle analysis, small-body resource identification, and/or quantification of potential small-body resources (e.g., oxygen, water, and other volatiles; hydrated minerals; carbon compounds; fuels; metals; etc.).
    - Advancements geared toward instruments that enable elemental or mineralogy analysis (such as high-sensitivity x-ray and UV-fluorescence spectrometers, UV-fluorescence systems, scanning electron microscopy with chemical analysis capability, mass spectrometry, gas chromatography and tunable diode laser sensors, calorimetry, imaging spectroscopy, and laser-induced breakdown spectroscopy (LIBS)).
  - Saturn, Uranus, and Neptune and their moons:
    - Components, sample acquisition, and instrument systems that can enhance mission science return and withstand the low temperatures/high pressures of the atmospheric probes during entry. Note that *in situ* instruments and components focused on ocean worlds life detection are specifically solicited in S13.06 and are encouraged to be submitted to S13.06.
  - The Moon:
    - This topic seeks advancement of concepts and components to develop a Lunar Geophysical Network as envisioned in the Planetary Decadal Survey. Understanding the distribution and origin of both shallow and deep moonquakes will provide insights into the current dynamics of the lunar interior and its interplay with external phenomena (e.g., tidal interactions with Earth). The network is envisioned to comprise multiple free-standing seismic stations that would operate over many years in even the most extreme lunar temperature environments.
    - Technologies to advance all aspects of the network including sensor emplacement, power, and communications in addition to seismic, heat flow, magnetic field and electromagnetic sounding sensors are desired.
    - This topic also seeks technologies for quantifying lunar water and measuring the D/H ratio in lunar water. Much evidence points to the presence of water ice at cold spots in the permanently shadowed regions at the lunar poles, with estimated abundance of ~5 to 10 wt%.
    - Technologies, concepts, or components related to active source (e.g., lidar) imaging systems for accurate and precise mobile 3D terrain mapping and navigation in lunar South Pole regions with extreme solar incidence conditions (e.g., long persistent shadows and direct solar interference), extreme lunar temperature variation, velocimetry, and with low size, weight, and power (SWaP) and solid-state or minimal moving parts.
  - General to Mars, Venus, Small bodies, Saturn and Uranus and Neptune and their moons, and the Moon:
    - Development of mass spectrometer front ends utilizing ion and acoustophoretic guides for a wide range of ions and macromolecules; Miniaturization of mass spectrometers by developing low-loss resonant inductive radio-frequency (RF) tanks at minimized volume and utilization of microelectromechanical system (MEMS) processes.

Novel instrument concepts are encouraged particularly if they enable a new class of scientific discovery. Technology developments relevant to multiple environments and platforms are also desired. Proposers should

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show an understanding of relevant space science needs and present a feasible plan to fully develop a technology and infuse it into a NASA mission.

**Expected TRL or TRL Range at completion of the Project:** 3 to 5

**Primary Technology Taxonomy:**

Level 1: TX 08 Sensors and Instruments

Level 2: TX 08.3 In-Situ Instruments/Sensor

**Desired Deliverables of Phase I and Phase II:**

- Analysis
- Prototype
- Hardware
- Software

**Desired Deliverables Description:**

The Phase I project should focus on feasibility and proof-of-concept demonstration (TRL 2-3). The required Phase I deliverable is a report documenting the proposed innovation, its status at the end of the Phase I effort, and the evaluation of its strengths and weaknesses compared to the state of the art. The report can include a feasibility assessment and concept of operations, simulations and/or measurements, and a plan for further development to be performed in Phase II.

The Phase II project should focus on component and/or breadboard development with the delivery of specific hardware for NASA (TRL 4-5). Phase II deliverables include a working prototype of the proposed hardware, along with documentation of development, capabilities, and measurements.

**State of the Art and Critical Gaps:**

In situ instruments and technologies are essential bases to achieve Science Mission Directorate's (SMD's) planetary science goals summarized in the Planetary Decadal Survey. In situ instruments and technologies play an indispensable role for NASA's New Frontiers and Discovery missions to various planetary bodies (Mars, Venus, small bodies, Saturn, Uranus, Neptune, Moon, etc.).

There are currently various in situ instruments for diverse planetary bodies. However, there are ever-increasing science and exploration requirements and challenges for diverse planetary bodies. For example, there is urgent need for exploring RSL (recurring slope lineae) on Mars and plumes from planetary bodies, as well as a growing demand for in situ technologies amenable to small spacecraft.

To narrow the critical gaps between the current state of art and the technology needed for the ever-increasing science/exploration requirements, in situ technologies are being sought to achieve much higher resolution and sensitivity with significant improvements over existing capabilities with lower mass, power, and volume.

**Relevance / Science Traceability:**

In situ instruments and technologies are essential bases to achieve the Science Mission Directorate's (SMD's) planetary science goals summarized in the Planetary Decadal Survey. In situ instruments and technologies play an indispensable role for NASA's New Frontiers and Discovery missions to various planetary bodies.

In addition to Phase III opportunities, SMD offers several instrument development programs as paths to further development and maturity. These include the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) Program, which invests in low-TRL technologies and funds instrument feasibility studies, concept formation, proof-of-concept instruments, and advanced component technology, as well as the Maturation of Instruments for Solar System Exploration (MatISSE) Program and the Development and Advancement of Lunar Instrumentation (DALI) Program, which invest in mid-TRL technologies and enable timely and efficient infusion of technology into planetary science missions.

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## References:

1. Li et al.: Direct evidence of surface exposed water ice in the lunar polar regions, *PNAS*, 115, 2018, pp. 8907-8912, <https://www.pnas.org/content/pnas/115/36/8907.full.pdf>
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3. Schultz, P.H.; Hermalyn, B.; Colaprete, A.; Ennico, K.; Shirley, M.; and Marshall, W.S.: The LCROSS cratering experiment, *Science*, 330, 2010, pp. 468-472.

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